

Published in final edited form as:

J Bone Miner Res. 2012 January ; 27(1): 187–194. doi:10.1002/jbmr.505.

Calcium Intake and Prostate Cancer Among African Americans: Effect Modification by Vitamin D Receptor Calcium Absorption Genotype

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Abstract

High dietary intake of calcium has been classified as a probable cause of prostate cancer although the mechanism underlying the association between dietary calcium and prostate cancer risk is unclear. The vitamin D receptor (VDR) is a key regulator of calcium absorption. In the small intestine, VDR expression is regulated by the CDX-2 transcription factor, which binds a polymorphic site in the VDR gene promoter. We examined VDR Cdx2 genotype and calcium intake, assessed by a food frequency questionnaire, in 533 African American prostate cancer cases (256 with advanced stage at diagnosis, 277 with localized stage) and 250 African American controls who participated in the California Collaborative Prostate Cancer Study. We examined the effects of genotype, calcium intake, and diet-gene interactions by conditional logistic regression. Compared to men in the lowest quartile of calcium intake, men in the highest quartile had an approximately two-fold increased risk of localized and advanced prostate cancer (odds ratio [OR]= 2.20, 95% confidence interval [CI]= 1.40, 3.46), with a significant dose-response. Poor absorbers of calcium (VDR Cdx2 GG genotype) had a significantly lower risk of advanced prostate cancer (OR= 0.41, 95% CI = 0.19, 0.90). The gene-calcium interaction was statistically significant ($p=0.03$). Among men with calcium intake below the median (680 mg/day), carriers of the G allele had an approximately 50% decreased risk compared to men with the AA genotype.

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Conflict of Interest:

No authors have conflicts of interest

Co-Authors' Roles in Study Conduct and Manuscript Preparation:

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Data Interpretation: All authors

Drafting Manuscript: All authors

Reviewing Manuscript: All authors

Approving Final Version of Manuscript: All authors

These findings suggest a link between prostate cancer risk and high intestinal absorption of calcium.

Keywords

Vitamin D receptor; calcium absorption; genetic polymorphism; prostate cancer; African American

Introduction

The relationship between diets high in calcium and risk of prostate cancer has been the subject of numerous epidemiologic studies. In a recent review of this literature, the World Cancer Research Fund (WCFR) classified calcium as a probable cause of prostate cancer¹. The Agency for Health Care Research and Quality (AHCQR) reached a similar conclusion². The assessment of the WCFR was based on examination of 9 cohort and 12 case-control studies. On meta-analysis, higher intake of calcium was associated with increased risk of prostate cancer, consistent with a dose-response relationship in the cohort studies. The AHCQR report considered that of the four cohort studies with the highest methodologic quality, three showed that diets high in calcium were associated with an increased risk of advanced or fatal disease. Recently, two prospective studies showed that serum levels of calcium that are high but within the normal reference range (high normocalcemia) were associated with a 2–3 fold increase in prostate cancer mortality^{3–4}. Because levels of ionized calcium in serum are increased after absorption of a moderate dose of calcium, we hypothesized that prostate cancer risk may be influenced by polymorphisms in genes that influence the efficiency of calcium absorption.

Many of the genes affecting calcium absorption are regulated by the vitamin D receptor (VDR)^{5–6}. In the small intestine, VDR expression is regulated by the tissue-specific transcription factor, CDX-2⁷ which binds a site in the VDR upstream 1e promoter⁸. This CDX-2 binding site harbors a single nucleotide A/G polymorphism (denoted Cdx2). The CDX-2 protein binds more efficiently to the A than to the G allele, and the A allele has been shown to more efficiently drive transcription in *in vitro* reporter gene assays⁹. The VDR Cdx2 low activity G allele has been associated consistently with lower bone mineral density in candidate gene studies¹⁰, and data from genome-wide association studies (GWAS) support these findings. Although the association did not attain genome-wide significance ($p=0.0007$), a SNP (rs7132324) tightly linked to the Cdx2 SNP ($D'=0.967$) was among the top 0.2% of hits for bone mineral density at the hip¹¹. Although the effect of the Cdx2 SNP on intestinal calcium absorption remains to be experimentally verified, these data suggest that the differences observed between alleles *in vitro* influence intestinal calcium absorption *in vivo*.

We hypothesized that the high activity A allele, which is common in populations of African origin, may contribute to the high prostate cancer incidence and mortality rates and younger ages at diagnosis observed in African Americans compared to other racial/ethnic groups^{12–13}. We examined dietary calcium intake and VDR Cdx2 genotype among 533 African American cases (256 with advanced stage at diagnosis; 277 with localized stage) and 250 African American controls from the California Collaborative Prostate Cancer Study, a population-based multiethnic case-control study that had a high proportion of cases diagnosed with aggressive prostate cancer.

Materials and Methods

Study Population

The study population from the San Francisco Bay area and Los Angeles County has been described in detail previously¹⁴. Cases were identified by the Greater Bay Area Cancer Registry, the Los Angeles County Cancer Surveillance Program, and the Los Angeles County Cancer Registry. Five hundred fifty-nine African American cases (including 377 from Southern California and 182 from Northern California) completed the interview. Twenty-six cases did not have definitive stage and were excluded, leaving 533 cases. Four hundred fifty-four cases (246 advanced and 208 localized) provided a biospecimen. Biospecimens were not collected from localized cases at the Northern California site.

In both studies, advanced prostate cancer was defined according to SEER (Surveillance Epidemiology and End Results) 1995 pathologic and clinical extent of disease codes. Of the 533 participating cases, 256 (116 from Northern California and 140 from Southern California) were diagnosed with advanced stage, 277 (66 from Northern California and 211 from Southern California) were diagnosed with localized disease.

Controls were identified through random-digit dialing and from random selections from the rosters of beneficiaries of the Health Care Financing Administration at the Northern California site and by a standard neighborhood walk algorithm¹⁵ at the Southern California site. Controls were frequency matched to cases on self-reported race/ethnicity and expected 5-year age distributions. Two hundred fifty controls (including 162 from Southern California and 88 from Northern California) completed the interview and 245 provided a biospecimen.

The study was approved by the Institutional Review Boards of the Cancer Prevention Institute of California (formerly the Northern California Cancer Center) and the University of Southern California. Written informed consent was obtained for all study participants.

Data Collection

Trained interviewers conducted in-person interviews and administered a structured questionnaire that asked about demographic background, lifestyle factors (physical activity, alcohol consumption, smoking), body size, use of supplements containing calcium, family history of prostate cancer in first-degree relatives, medical history and screening for prostate cancer. A 74-item food frequency questionnaire adapted from Block's Health History and Habits Questionnaire¹⁶ assessed usual dietary intake during the reference year, defined as the calendar year before diagnosis for cases and the year before selection into the study for controls. The interviewers also took three measurements of standing height and weight which were averaged. Calcium intake was assessed from single calcium tablets, multivitamin pills, and calcium-based antacids, such as Tums, Rolaids, Alka-Mints or Chooz Antacid gum. Data were collected on age at first use, frequency of use, and duration of use.

Exposure Variables

Dietary questionnaires from subjects reporting total energy intake greater than 6000 or less than 600 kilocalories per day (33 cases and 10 controls) were considered to be unreliable and were excluded from the analysis, leaving 500 cases and 240 controls with dietary information.

We derived two measures of calcium exposure, including total calcium from foods, beverages and supplements, and dietary calcium from foods and beverages only. Cut points were selected based on the calcium intake of controls. Calcium supplementation was divided

into dichotomous categories reflecting usual daily calcium contained in multivitamins (400 mg/day) vs. less than 400 mg/day. Body mass index (BMI) was calculated as reported weight in the reference year (in kg) divided by measured height squared (in meters [m]) and dichotomized as obese (BMI ≥ 30) and non-obese (BMI <30).

Genotyping

The CDX-2 protein binding site SNP¹⁰ (rs11568820) was genotyped on the TaqMan 7900HT Sequence Detection System using the TaqMan Core Reagent Kit (Applied Biosystems, Foster City, CA). PCR reactions were carried out as recommended by the manufacturer. The following primer and minor groove binder probe sequences were used: forward primer 5'-CATTGTAGAACATCTTTTGTATCAGGAACT-3', reverse primer 5'-GGTCTTCCCAGGACAGTATTTTCA-3', G allele FAM- AGGTCACAGTAAAAAC-3', and A allele VIC-AGGTCACAATAAAAAAC-3'. Ten percent of samples were blindly replicated and samples with known genotype were included as controls on each run. Clusters were manually called without knowledge of case-control status. There were no discrepancies among replicate samples. Genotypes were called for 447 cases and 233 controls, giving a call rate of 97%.

Statistical Analysis

Allele frequencies were estimated by gene counting. Tests for departures from Hardy-Weinberg equilibrium among controls were conducted by comparing observed and expected genotype frequencies using a Chi Square test.

A matching variable for conditional logistic regression was constructed by creating study site/socio-economic status (SES) bins, as previously described¹⁴. Odds ratios (OR) and 95% confidence intervals (CI) were estimated by fitting conditional logistic regression models, using study site/SES as the matching variable and adjusting for age (continuous variable) and family history of prostate cancer in first-degree relatives (yes or no). Calcium was categorized according to quartiles among the controls. Dose-response trends were assessed by including quartile as an ordinal variable in logistic regression models. Tests of interaction were conducted by including cross-product terms in the conditional logistic models and conducting a 1 degree of freedom likelihood ratio test.

Results

Characteristics of participants are shown in Table 1. The median age at diagnosis was 64 years. On average, advanced cases were three years younger at diagnosis than localized cases. Cases and controls were similar with respect to education, socioeconomic status, and body mass index. Cases were more likely to report a family history of prostate cancer and consumed more calcium than did controls.

The majority of participants (82% of cases and 76% of controls) consumed less than the recommended intake of 1200 mg of calcium per day¹⁷. The predominant sources of dietary calcium were similar for cases and controls: dairy products (45%), followed by vegetables (predominantly spinach, other greens, and broccoli) (25%), and grains (including corn tortillas) (15%). Dietary calcium and total calcium showed similar patterns of increased risk of both advanced and localized disease associated with increasing intake (Table 2). Men in the highest quartile of total calcium intake (> 1059 mg/day) had a more than two-fold increased risk of prostate cancer (advanced or localized) vs. men in the lowest quartile (<488 mg/day) (OR = 2.20, 95% CI= 1.40, 3.46, p for trend= 0.01). Intake of calcium from supplements was low, with fewer than 5% of men consuming at least 400 mg/day of

supplemental calcium. However, consumers of 400 mg/day or more had a significantly increased risk for advanced prostate cancer (OR= 3.15, 95% CI= 1.09, 9.15) (Table 2).

The VDR Cdx2 minor (G) allele frequency was 28%. Genotype frequencies among the controls were in Hardy-Weinberg equilibrium. The VDR Cdx2 genotype was significantly associated with advanced, but not localized, prostate cancer (Table 3). Risk decreased with increasing number of G alleles (p trend = 0.02). Compared to men with genotype AA, those with the GG genotype were 59% less likely to have been diagnosed with advanced prostate cancer. When combining all cases (advanced plus localized), the reduction in risk for genotype GG vs. AA was slightly attenuated (42%) and was of borderline statistical significance ($p=0.09$).

The relationship between Cdx2 genotype and risk of advanced prostate cancer was modified by calcium intake (p for interaction = 0.03) (Table 3). Among men with calcium intake below the median, carriers of the G allele had an approximately 50% decreased risk compared to those with genotype AA. Among men with calcium intake above the median, Cdx2 G alleles were not associated with reduced risk of advanced prostate cancer. There was no association between Cdx2 genotype and risk of localized prostate cancer, regardless of the level of calcium intake. High calcium intake was a risk factor for advanced prostate cancer among men of all genotypes (Table 4), although the association was of borderline statistical significance among men with genotype AA ($p=0.08$).

The relationship between dietary calcium and prostate cancer risk was modified by obesity (Table 5). High calcium intake was a risk factor among both obese and non-obese men, although the association appeared to be stronger among the obese (p for interaction = 0.06). Data were too sparse to determine whether the relationship between VDR Cdx2 genotype and prostate cancer risk was modified by obesity, since genotype was a risk factor only for advanced disease.

Discussion

Our finding of an association between dietary calcium and prostate cancer risk is consistent with a sizable literature on dietary calcium and prostate cancer (see reviews^{18–19}). However, few studies have examined genotypes related to calcium absorption. To our knowledge, the VDR Cdx2 polymorphism has been examined in four prostate cancer studies, with inconsistent findings. Two studies examined the Cdx2 polymorphism with respect to sun exposure and prostate cancer risk. A UK study in an exclusively Caucasian population found a two-fold increased risk among carriers of the A allele, consistent with our findings, but that finding was limited to men with high sunlight exposure²⁰ [Bodiwala et.al, 2004]. Conversely, in a U.S. study of non-Hispanic white men, we found no significant association between VDR Cdx2 genotype and advanced prostate cancer risk, regardless of sun exposure²¹. Cdx2 genotype was examined in conjunction with serum vitamin D levels in the Physician's Health study²². Although there was a significant interaction between VDR Cdx2 genotype and vitamin D status, genotype was not significantly related to prostate cancer risk within strata defined by serum 25(OH)D levels (deficient/sufficient). Finally, in a study that did not examine vitamin D status or sunlight exposure, Torkko et al. found a borderline significant association between the A allele and decreased prostate cancer risk, among Hispanic but not among non-Hispanic White men²³.

Our finding that the high transcription A allele is associated with increased prostate cancer risk is not explained by the well-documented anti-proliferative, pro-differentiating effects of the VDR and its ligands on prostate epithelial cells²⁴. Increased expression of VDR in the prostate should decrease, not increase, risk. Furthermore, VDR Cdx2 genotype should not

affect prostatic VDR expression in the absence of the CDX-2 transcription factor, which is generally believed to be restricted to the intestine. However, it is noteworthy that CDX-2 expression has been reported in some other organs, including the prostate. In 70 radical prostatectomy specimens, Herawi et al. observed CDX-2 staining in 5.7% of the specimens. No staining was observed in any of 185 metastatic prostate tumors²⁵. The role of this protein in prostate tissue is presently unclear. However, the relative rarity of its expression suggests that it is unlikely to significantly influence the results of this study.

We believe that our findings are intelligible on the hypothesis that high calcium absorption genotypes and/or diets high in calcium increase serum calcium levels and the increase in serum calcium affects prostate cancer cells. Prostate cells, including prostate cancer cells, possess both the calcium-sensing receptor²⁶ and calcium-dependent voltage-gated channels²⁷ which respond to an increase in calcium with an increase in proliferation and a decrease in apoptosis. Levels of total serum calcium are generally very stable, and are little influenced by dietary intakes over a wide range of intake²⁸. However, the results of carefully conducted metabolic studies indicate that serum levels of ionized calcium, the biologically active fraction of total serum calcium, increase significantly for several hours after calcium intake^{29–30}. High normal levels of serum and ionized serum calcium have been associated with increased risk of fatal prostate cancer in two prospective epidemiologic studies^{3–4}. Because serum calcium is presumed to promote prevalent (existing) cancer, rather than having an effect on the initiation of cancer, this interpretation is consistent with the observation that VDR Cdx2 genotype was associated with advanced but not localized disease.

For advanced disease, we observed a statistical interaction between dietary calcium intake and genotype. The high absorption variant conferred less risk among men consuming higher levels of calcium. Although vitamin D aids calcium absorption, on a typical diet containing 1000 mg of calcium, the majority of calcium absorption is passive (vitamin D-independent)³¹. The passive absorption of calcium may explain why men who consume greater amounts of calcium are at increased prostate cancer risk, regardless of genotype.

We also observed a borderline significant interaction between calcium intake and obesity, with calcium being a stronger risk factor among the obese than the non-obese. This finding contrasts with a report from the Singapore Health Study which found calcium to be a risk factor only among thin men (BMI < 22.9 kg/m²)³². However the interaction between calcium and BMI in that study was not statistically significant.

Although numerous studies indicate that calcium is associated with an increased risk of prostate cancer, particularly of advanced and/or fatal disease, other studies have suggested that adequate (vs. deficient) levels of 25-OHD are associated with a decreased risk of subsequent prostate cancer. As the “classic” role of vitamin D is to increase the efficiency of calcium uptake, the literature for serum vitamin D and for calcium appears conflicting. However this apparent conflict can be understood by considering the “non-classical” (autocrine/paracrine) role of vitamin D in the prostate. Prostate cells possess 1- α hydroxylase and convert 25-OHD into 1,25(OH)₂D, which exerts prodifferentiating and antiproliferative effects on prostate cancer cells³³. Thus the classical (calcium-mediated) and non-classical roles of vitamin D operate “against” each other to influence prostate cancer risk, probably through different mechanisms. Although it had been speculated that the increased risk for prostate cancer that is associated with higher levels of dietary calcium was due to a reduction in the hepatic conversion of 25-OHD into 1,25(OH)₂D by calcium³⁴, this hypothesis has not been supported by subsequent investigations³⁵.

It is important to note that although some studies have reported an increased risk of prostate cancer with low levels of vitamin D^{21,36}, these have not been confirmed by some other investigations. Many subsequent studies of serum 25-OHD and prostate cancer risk have been null, and some have reported an increased risk of prostate cancer with both low and high levels of 25-OHD^{37–38}. A positive effect of serum calcium on prostate cancer risk may confound the relationship between 25(OH)D and prostate cancer risk in some studies, which may account for some discrepant results in the literature³⁹.

Our study has several limitations, including its retrospective design which could have introduced recall bias in the reporting of calcium intake. However, our findings for calcium intake are consistent with those of several prospective studies, where recall bias obviously is not a contributor. Similarly, although we measured calcium intake, we did not measure serum calcium. Future studies would benefit from including measurements of serum total and ionized calcium.

Strengths of the study include its population-based design and the oversampling of cases with advanced-stage disease, which allowed us to distinguish stage-specific genotype-diet interactions that would have been difficult or impossible to detect in a case series that consisted mainly of early-stage disease. Finally, few epidemiologic studies of diet and prostate cancer have included large numbers of African American cases.

Population stratification is a potential confounding issue in our study. The VDR Cdx2 A allele is associated with both increased prostate cancer risk and with African ancestry. It could be that the A allele is simply marking those men with increased African ancestry and therefore at increased risk due to some other factor that is associated with African ancestry. In fact, among the 518 men for whom genetic ancestry estimates were available, adjusting for European ancestry did not alter the results. The ancestry-adjusted odds ratio comparing genotype GG to AG/AA for advanced cases vs. controls was 0.37 after ancestry adjustment (vs. an unadjusted OR of 0.38).

The more active A allele is most prevalent in populations of African origin (98% in Yorubans in Ibadan, 89% in Luhya in Kenya, 71% in African Americans of the U.S. Southwest; in contrast to 45% in Japanese in Tokyo, Japan and 20% in Utah residents with ancestry from northern and western Europe)⁴⁰. Prostate cancer incidence rates in African Americans are 36% higher than those of non-Hispanic Whites, and African Americans are diagnosed at younger ages and are twice as likely to die of the disease (SEER 2003–2007)¹³. Therefore, by promoting efficient calcium absorption even on a relatively low calcium diet, the ancestral African VDR Cdx2 allele may contribute to racial/ethnic disparities in prostate cancer incidence and mortality.

In conclusion, our data support the hypothesis, substantiated in many epidemiologic studies, that dietary calcium is causally related to prostate cancer risk^{18–19}. Our finding that prostate cancer risk is increased among high absorbers of calcium adds to the biological plausibility of the calcium hypothesis, for which the underlying mechanism has been a subject of considerable debate^{34–35,41–42}. Because calcium is essential for bone health and appears to protect against colorectal cancer (and possibly other diseases)¹, we must be cautious about making public health recommendations to limit calcium intake. Our data indicate that, although calcium intake increases prostate cancer risk in African American men as a group, it is associated with a significantly greater risk among high absorbers of calcium (men with the AA genotype). If confirmed by other dietary-seroepidemiologic studies, African American men with the AA genotype may be advised to restrict their calcium intake in order to reduce their risk of developing prostate cancer.

Acknowledgments

Financial support was received from the University of Southern California T32-ES013678 Training Grant from the National Institutes of Environmental Health Sciences (to GWR).

The Northern and Southern California studies were funded by grants 99-00527V-10182 (to E.M.J.) and 99-00524V-10258 (to S.A.I.) from the Cancer Research Fund, under Interagency Agreement #97-12013 (University of California contract #98-00924V) with the Department of Health Services Cancer Research Program and by grant R01CA84979 (to S.A.I.) from the National Cancer Institute, National Institutes of Health. Cancer incidence data used in this publication have been collected by the Greater Bay Area Cancer Registry, of the Northern California Cancer Center, under contract N01-PC-35136 with the National Cancer Institute, National Institutes of Health, and with support of the California Cancer Registry, a project of the Cancer Surveillance Section, California Department of Health Services, under subcontract 1006128 with the Public Health Institute and the Los Angeles Cancer Surveillance Program of the University of Southern California with Federal funds from the National Cancer Institute, National Institutes of Health, Department of Health and Human Services, under Contract No. N01-PC-35139, and the California Department of Health Services as part of the statewide cancer reporting program mandated by California Health and Safety Code Section 103885, and grant number 1U58DP000807-3 from the Centers for Disease Control and Prevention. Mention of trade names, commercial products, specific equipment or organizations does not constitute endorsement, guarantee or warranty by the State of California Department of Health Services or the U.S. Government, nor does it imply approval to the exclusion of other products. The views expressed in this publication represent those of the authors and do not necessarily reflect the position or policies of the Northern California Cancer Center, the California Public Health Institute, the State of California Department of Health Services, or the U.S. Department of Health and Human Services. Support from the American Cancer Society to GGS (Pilot and Exploratory Grants in Cancer Palliation) is gratefully acknowledged.

We are grateful to the men who participated in this study, without which this research would not be possible.

Abbreviations

VDR	Vitamin D (1,25- dihydroxyvitamin D3) receptor protein
VDR gene	gene encoding the vitamin D3 receptor
CDX-2	caudal type homeo box transcription factor 2 protein
Cdx2	single nucleotide polymorphism in the CDX-2 binding site of the VDR gene
OR	Odds ratio
CI	Confidence interval

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Table 1

Characteristics of Prostate Cancer Cases and Controls

	Controls	Cases	
	N=250	N= 533	
		Advanced	Localized
	(N=250)	(N=256)	(N=277)
	N (%)	N (%)	N (%)
Age (years)			
<=49	17 (7%)	15 (6%)	13 (5%)
50–59	63 (25%)	79 (31%)	56 (20%)
60–69	105 (42%)	106 (41%)	114 (41%)
70–79	60 (24%)	53 (21%)	78 (28%)
>=80	5 (2%)	3 (1%)	16 (6%)
mean (SD)	63.5 (9.15)	62.7 (8.46)	65.8 (8.85)
Education			
High School or less	99 (40%)	120 (47%)	120 (43%)
College Degree/Some College	95 (38%)	79 (31%)	111 (40%)
Post Graduate	49 (20%)	57 (22%)	45 (16%)
Unknown	7 (2%)	0 (0%)	1 (<1%)
SES (census tract-based)			
1 = Low	51 (20%)	69 (27%)	96 (35%)
2	71 (28%)	54 (21%)	70 (25%)
3	57 (23%)	63 (25%)	58 (21%)
4	48 (19%)	45 (18%)	33 (12%)
5= High	23 (9%)	25 (10%)	20 (7%)
Family History of Prostate			
Cancer	217 (87%)	195 (76%)	214 (77%)
No	28 (11%)	61 (24%)	63 (23%)
Yes	5(2%)	0 (0%)	0(0%)
Unknown	Mean (SD)	Mean (SD)	Mean (SD)
BMI (Kg/m ²)	28.8 (5.5)	28.3 (5.5)	28.5 (4.8)
Calcium Intake			
Total Calcium (mg/day)	818 (474)	979 (577)	945 (510)
Dietary Calcium (mg/day)	755 (444)	890 (517)	869 (497)
Supplemental Calcium (mg/day)	64 (155)	89 (217)	75 (130)

TABLE 2

Total, Dietary and Supplemental Calcium Intake and Prostate Cancer Risk

	Controls N=240		All Cases vs. Controls N=500		Advanced Cases vs. Controls N=235		Localized Cases vs. Controls N=265	
	N (%)	OR (95% CI)	N (%)	OR (95% CI)	N (%)	OR (95% CI)	N (%)	OR (95% CI)
Total Calcium[†]								
<488 mg/day	61 (25%)		84 (17%)	1.0 (ref)	41 (17%)	1.00 (ref)	43 (16%)	1.00 (ref)
488 – 680 mg/day	59 (25%)		75 (15%)	0.91 (0.56, 1.47)	34 (14%)	0.84 (0.47, 1.51)	41 (15%)	0.96 (0.54, 1.71)
681–1059 mg/day	61 (25%)		162 (32%)	1.89 (1.21, 2.97)	77 (33%)	1.87 (1.10, 3.19)	85 (32%)	1.89 (1.11, 3.21)
> 1059 mg/day	59 (25%)		179 (36%)	2.20 (1.40, 3.46)	83 (35%)	2.08 (1.22, 3.53)	96 (36%)	2.14 (1.26, 3.62)
p for Trend				p< 0.001		p = 0.001		p= 0.001
Dietary Calcium								
<449 mg/day	60 (25%)		77 (15%)	1.0 (ref)	34 (14%)	1.00 (ref)	43 (16%)	1.00 (ref)
449 – 633 mg/day	60 (25%)		94 (19%)	1.19 (0.74, 1.92)	44 (19%)	1.30 (0.72, 2.33)	50 (19%)	1.09 (0.62, 1.90)
634–973 mg/day	60 (25%)		149 (30%)	1.87 (1.18, 2.97)	71 (30%)	2.11 (1.21, 3.68)	78 (29%)	1.60 (0.94, 2.74)
> 973 mg/day	60 (25%)		180 (36%)	2.26 (1.43, 3.57)	86 (37%)	2.48 (1.43, 4.28)	94 (35%)	1.94 (1.14, 3.30)
p for Trend				p= 0.001		p = 0.001		p = 0.005
Supplements								
< 400 mg/day	235 (98%)		479 (96%)	1.0 (ref)	222 (94%)	1.00 (ref)	257 (97%)	1.00 (ref)
> = 400 mg/day	5 (2%)		21 (4%)	2.50 (0.92, 6.79)	13 (6%)	3.15 (1.09, 9.15)	8 (3%)	1.86 (0.58, 5.98)

[†]Total Calcium is dietary calcium plus calcium supplements

Models adjusted for age and family history of prostate cancer

TABLE 3

VDR CDX-2 Polymorphism and Prostate Cancer Risk

	Controls	All Cases vs Controls		Advanced Cases vs Controls		Localized Cases vs Controls	
	N=223	N = 414		N=222		N=192	
VDR-CDX2	N (%)	N (%)	OR (95% CI)	N (%)	OR (95% CI)	N (%)	OR (95% CI)
AA	123 (55%)	252 (61%)	1.0 (ref)	140 (63%)	1.0 (ref)	112 (58%)	1.0 (ref)
AG	78 (35%)	137 (33%)	0.88 (0.61, 1.27)	71 (32%)	0.78 (0.51, 1.18)	66 (34%)	1.06 (0.67, 1.66)
GG	22 (10%)	25 (6%)	0.58 (0.31, 1.09)	11 (5%)	0.41 (0.19, 0.90)	14 (7%)	0.74 (0.35, 1.59)
p for trend			p = 0.12		p = 0.02		p = 0.67
Stratified By Total Calcium Intake							
	Controls	All Cases vs Controls		Advanced Cases vs Controls		Localized Cases vs Controls	
Low Calcium <=680(mg/day)	N= 111	N = 126		N=71		N=55	
VDR-CDX2	N (%)	N (%)	OR (95% CI)	N (%)	OR (95% CI)	N (%)	OR (95% CI)
AA	59 (53%)	84 (67%)	1.0 (ref)	51 (72%)	1.0 (ref)	33 (60%)	1.0 (ref)
AG	37 (33%)	38 (30%)	0.69 (0.38, 1.26)	19 (27%)	0.54 (0.27, 1.12)	19 (35%)	1.08 (0.50, 2.30)
GG	15 (14%)	4 (3%)	0.18 (0.05, 0.60)	1 (1%)	0.08 (0.01, 0.62)	3 (6%)	0.40 (0.10, 1.63)
p for trend			p = 0.005		p = 0.002		p = 0.38
High Calcium >680(mg/day)	N= 112	N=288		N= 151		N= 137	
VDR-CDX2	N%	N (%)	OR (95% CI)	N(%)	OR* (95% CI)	N(%)	OR*(95% CI)
AA	64 (57%)	168 (58%)	1.0 (ref)	89 (59%)	1.0 (ref)	79 (58%)	1.0 (ref)
AG	41 (37%)	99 (34%)	1.00 (0.62, 1.61)	52 (34%)	0.93 (0.55, 1.58)	47 (34%)	1.05 (0.59, 1.86)
GG	7 (6%)	21 (7%)	1.18 (0.47, 2.96)	10 (7%)	0.92 (0.33, 2.58)	11 (8%)	1.15 (0.41, 3.23)
p for trend			p = 0.81		p = 0.79		p = 0.49
p for interaction			p = 0.03		p = 0.03		p = 0.78

Models adjusted for age and family history of prostate cancer

TABLE 4

Advanced Prostate Cancer and VDR CDX-2 Polymorphism Stratified by Total Calcium Intake

Genotype	Total Calcium		
VDR-CDX-2	Low Calcium < = 680 mg/day	High Calcium > 680 mg/day	
	OR (95% CI)	OR (95% CI)	p - value
AA	1.00 (ref)	1.58 (0.95, 2.63)	p= 0.08
AG /GG	0.43 (0.22, 0.82)	1.44 (0.83, 2.49)	p= 0.01
p for trend	p = 0.03	p = 0.70	

Model adjusted for age and family history of prostate cancer

TABLE 5

Total Calcium Intake and Prostate Cancer Risk, Stratified by Obesity

<30 BMI (Non-Obese)	Controls	All Cases vs. Controls	
	N = 161	N = 353	OR (95% CI)
Total Calcium[†]	N (%)	N (%)	
< = 680 mg/day	81 (50%)	128 (36%)	1.0 (ref)
> 680 mg/day	80 (50%)	225 (64%)	1.80 (1.23, 2.65)
p for trend			p=0.003
> = 30 BMI (Obese)	Controls	All Cases vs. Controls	
	N = 78	N = 152	OR (95% CI)
Total Calcium[†]	N (%)	N (%)	
< = 680 mg/day	38 (49%)	29 (21%)	1.0 (ref)
> 680 mg/day	40 (56%)	116 (79%)	3.70 (1.99, 6.90)
p for trend			p <0.01
p for Interaction			p= 0.06

[†]Total Calcium= dietary calcium and supplements

Models adjusted for age and family history of prostate cancer